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Poster paper

Stability of NSLS-II girder-magnet assembly

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The low-emittance design of the NSLS-II (a new state-of-the-art medium energy third-generation storage ring) requires that the uncorrelated vertical RMS motion between the multipole magnets on a girder be less than 25 nm. The stability of the girder-magnet assembly is affected by factors such as ambient vibration, temperature fluctuations and diurnal floor motion in the storage ring. In this paper we discuss the design features of a high-stability girder-magnet assembly for the NSLS-II.

1. Introduction

To realize the benefits of the high brightness and small beam sizes of NSLS-II, there are stringent stability requirements. The electron beam has a minimum vertical size of 3 μm in the centre of the short straight section. The stability requirement of 10 % or better of the beam's size requires that the uncorrelated vertical RMS motion between the multipole magnets on a girder be less than 25 nm based on a closed orbit amplification of ~ 10 . Further, the random motion of the girders is required to be less than 70 nm. The horizontal stability tolerances are relaxed compared to the vertical by a factor of ~ 7 because of the larger beam size in that direction.

2. Stability of NSLS-II girder magnet

2.1. Short term (<1 h, ground vibration)

In a previous study, we have shown that the amplification of the ground motion in the 4–100 Hz range (~ 15 nm at the NSLS-II site) can be suppressed by an over-constrained girder fixed at eight locations on bolts of 2 in. diameter (overall length of the bolts is ~ 6 in.) (Ravindranath *et al.* 2008). In the same study, we further showed that a tightening torque of 1000 ft lbs on these bolts was necessary to ensure a stiff system. The modal analyses and vibration tests confirmed that for this system the first fundamental mode (rocking mode) of vibration has a natural frequency of ~ 30 Hz in which all the magnets move in phase, and the second

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mode (twisting mode) has a frequency of ~ 50 Hz in which the magnets move out of phase (uncorrelated motion between the magnets). Above 30 Hz there is a sharp drop in the ground motion (excitation signal) and the RMS value is less than 1 nm. From the theory of vibration we know that since the frequency associated with the twist mode of vibration (uncorrelated magnet motion) is far away from the low-frequency-large-motion range, the amplification factor will be close to 1.

2.2. Medium term (1 h, thermal fluctuations)

To ensure acceptable thermal deformations of the ring components, process water and tunnel air temperatures will be maintained to within ± 0.05 and $\pm 0.1^\circ\text{C}$, respectively, of their nominal values. Both finite-element analysis (FEA) and test results confirmed that for a tunnel air temperature change of $\pm 0.1^\circ\text{C}$ with 1 h time cycle, the girder (having large thermal mass) sees only $\sim 1/10$ th of the ambient temperature change (figure 1a). FEA calculations showed that resulting girder deflection corresponding to a girder ΔT of 0.01°C will be less than 25 nm (figure 1b). The accuracy of the FEA model was verified by measuring the absolute displacement (not deflection) on the bottom plate of the girder for a given temperature variation with a displacement sensor (Subminiature Gauging Differential Variable Reluctance Transducer (SG-DVRT) with a resolution of 15 nm) manufactured by Microstrain.

2.3. Medium term (1–12 h, diurnal floor motion)

Synchrotron facilities such as the Photon Factory (Japan) (Katsura *et al.* 1992) and SSRF (China) (Y. Lixin and W. Jun, private communication) have measured diurnal circumference variation as large as $1\ \mu\text{m m}^{-1}$. Floor temperature measurements show that even though the tunnel floor temperature is stable to $\pm 0.02^\circ\text{C}$, the experimental hall floor which sees larger temperature excursions can drag the tunnel floor (because of monolithic connection). Considering a coefficient of thermal expansion of $\sim 10\ \mu\text{m}^{-1}\ \text{m } ^\circ\text{C}^{-1}$ for concrete, analyses and thermal tests have shown that a bulk ΔT of 0.1°C in the experimental floor can easily result in the observed tunnel floor motion of $1\ \mu\text{m m}^{-1}$. The stiff and over-constrained (grouted interface between the girder floor plate and the concrete floor) girder

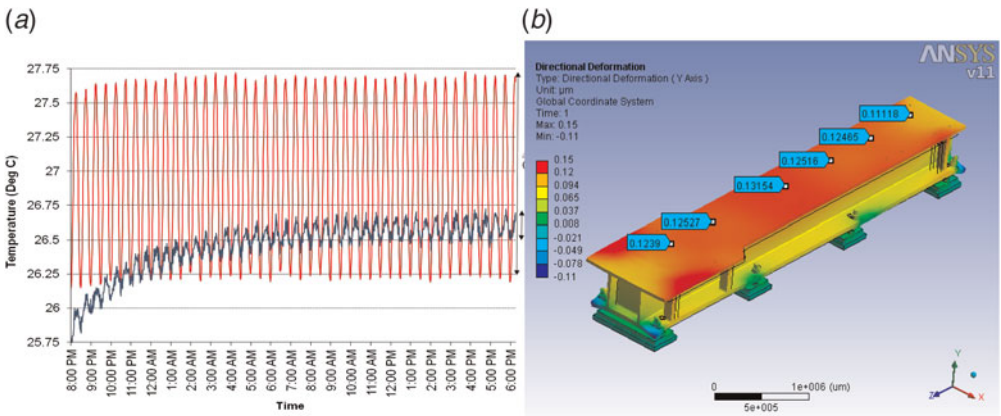


FIGURE 1. (a) Time-temperature Girder response (ΔT_{Girder} (blue curve) = $(1/10) \Delta T_{\text{Air}}$ (red curve)), (b) FEA girder deflection (girder deflection < 25 nm for $\Delta T_{\text{Girder}} \sim 0.01^\circ\text{C}$).

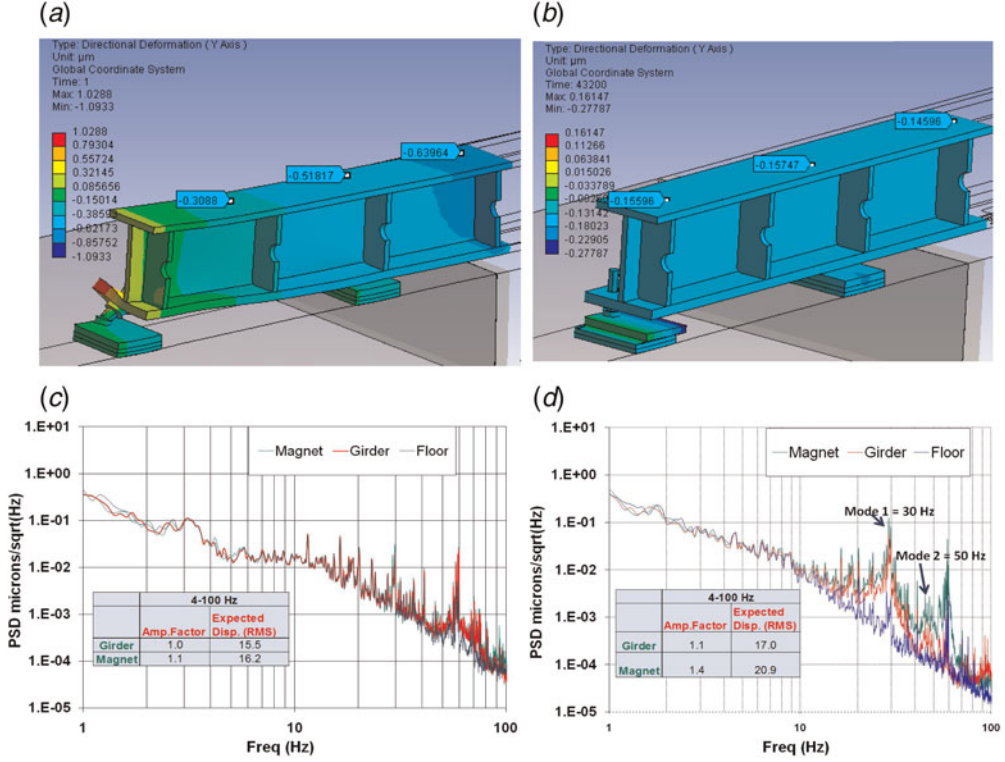


FIGURE 2. (a) Deflection >200 nm without viscoelastic, (b) deflection <25 nm with viscoelastic, (c) vertical $\sqrt{\text{PSD}}$ and (d) horizontal $\sqrt{\text{PSD}}$.

resists this longitudinal floor motion ($1 \mu\text{mm}^{-1}$) by bending-type deformations, resulting in a vertical deflection, 10 times greater than the required magnet stability tolerance (figure 2a). To relax the over-constrained condition without losing vibration stability we evaluated the concept of making the mounting base of the girder as a viscoelastic sandwich with thick top and bottom steel plates. The intermediate adhesive film of viscoelastic material (3M) allows relative displacement between the plates to absorb the slow diurnal floor motion without causing the girder to deform (<25 nm) (figure 2b). Vibration tests done on this configuration showed a slight improvement in the horizontal amplification factor as well because of the vibration damping property of the viscoelastic material (figure 2c,d).

3. Conclusion

The NSLS-II girder-magnet assembly is a stiff and over-constrained system to prevent amplification of the ambient vibration. Regulation of the process water and tunnel air temperature fluctuations to within ± 0.05 and $\pm 0.1^\circ\text{C}$ with <1 h time cycle will ensure acceptable thermal deformation of the girder. The effect of diurnal floor motion on the vertical stability will be mitigated by incorporating a viscoelastic sandwich design for the mounting base of the girder.

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